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Existing doctrinal guidance for preventing heat injury in military settings is based on measurements of the Wet Bult Globe Temperature (WBGT) index. An existing military WBGT measurement device (NSN 6665-00-159-2218) was employed by a U.S. Army Reserve unit during field training exercises at Fort Bliss, TX in 1986, Tinker AFB, OK in 1987, and Fort Hood, TX in 1988. The majority of heat casualties seen in these three exercises (31 out of 35) occurred when the daily maximum WBGT index exceeded 85°F. Experiences of this unit suggest that a strictly enforced, WBGT-based, heat injury prevention program was effective in minimizing both the number and severity of heat-related injuries. During the exercises at Fort Hood in 1988, a preliminary evaluation of methods to obtain WBGT information from polar orbiting weather satellites was conducted. Data from 11 satellite passes were obtained and the average error, or bias, of the satellite-derived WBGT values was found to be -1.8°F (too low) with a variation (standard deviation) of ±3.7°F around that bias. Work is in progress to improve this future heat stress assessment technology.

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FIELD ASSESSMENT OF WET BULB GLOBE TEMPERATURE - PRESENT AND FUTURE

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DISCLAIMER STATEMENT

The views of the authors do not purport to reflect the positions of the Department of the Army or the Department of Defense.

INTRODUCTION

It is of utmost importance for Army reserve units to monitor wet bulb globe temperature (WBGT) when deployed for training under field conditions which have the potential for inducing heat injury. The need for WBGT monitoring is amplified by the fact that many reservists generally work in air conditioned environments and are unacclimatized to heat. In the event of mobilization, reserve units may be rapidly deployed to regions where extreme heat is a major environmental factor. Rapid deployment and mission requirements may not allow sufficient time for heat acclimatization. Thus, WBGT monitoring is essential to safely maximize the activities of unacclimatized troops under heat stress and minimize the risk of heat injury. We are reporting on our experiences with heat stress measurements made during three field training exercises (FTX's): two used current WBGT measurement technology and the third evaluated the accuracy of WBGT estimates obtained using satellite remote sensing technology.

METHODS

The 44th Medical Evacuation Hospital is a 400 bed Army reserve unit located in Oklahoma City, OK. Members of the unit participated in a 5-day FTX at Fort Bliss, TX in June 1986 (233 reservists), a 1-day FTX at Tinker AFB, OK in August 1987 (145 reservists), and an 8-day FTX at Fort Hood, TX in June 1988 (229 reservists).

The primary purpose of the WBGT measurements made during these FTX's was to implement existing WBGT-based doctrinal guidance (1,2,3) in support of the training mission. The routine WBGT measurements and heat casualty information reported here were not obtained as part of a comprehensive, controlled, formal scientific study design. Although the typical uniform in these FTX's consisted of Battledress Uniform (BDU), boots, helmet, and Load Bearing Equipment (LBE) with canteen, individual physical activity level demands within the unit were, with the exception of the compass and obstacle course exercises, extremely variable. Consequently, the retrospective analysis of heat casualty occurrences is limited to observations based

on measured WBGT and broad categorization of physical activity levels (light, moderate, and heavy work categories are defined as metabolic rates approximating 250, 425, and 600 Watts respectively) and the severity of heat injuries (heat cramps, heat exhaustion, and heatstroke).

The unit had received recurrent training in heat stress and water discipline since 1986 and, since that time, WBGT has been monitored by this unit for all FTX's occurring in hot environments. The Weksler WBGT kit (NSN 6665-00-189-2218), a portable device, was used to obtain WBGT during all three FTX's. In addition, during the 8-day FTX at Fort Hood, seven portable electronic WBGT data loggers (Metrosonics Inc.) were deployed within a 1 km square area around the hospital site at Fort Hood. These automated instruments, recording WBGT at 1 minute intervals, provided the average ground WBGT value to the nearest minute of satellite over-pass. Satellite data were obtained from the Advanced Very High Resolution Radiometer (AVHRR) and TIROS Operational Vertical Sounder (TOVS)

instruments aboard National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites. Using methods being jointly developed by Gulf Weather Corporation and the Army, these data were processed by Gulf Weather Corporation to provide estimates of the prevailing surface level WBGT for the 44th Evacuation Hospital location at Fort Hood (4,5).

RESULTS

In June 1986, 233 reservists from the 44th Medical Evacuation Hospital deployed to Fort Bliss, Texas for annual training. During a 5-day period, June 5 to June 9, when the hospital was in full simulated field operation, WBGT was monitored daily between 0900 and 1800 hrs using the Weksler kit. Hourly WBGT information was communicated to Headquarters, 341st Medical Group which then forwarded it to all units under its command and control. Work levels ranged from light to intermittent heavy. Thirteen heat casualties were seen during this FTX. On June 5 and June 7, maximum WBGT readings of 90 and 93°F respectively

contributed to 9 heat casualties on these two days (Figure 1). All had heat exhaustion except for 1 case of heat cramps; no heatstroke was observed. All patients recovered following rest in the shade and rehydration with cooled water or carbonated beverages. On June 7, when the WBGT reached 93°F at 1400, the exercise was halted for a 2-hour period on orders of the Commander, 341st Medical Group. During the interval, all troops rested in a shady area and no additional heat injuries occurred to unit personnel.

During the 1-day FTX in August 1987 at Tinker Air Force Base, OK, 145 reservists from the 44th Evacuation Hospital were divided into groups of 10 - 15 soldiers. Each group negotiated a 1500 meter compass and obstacle course under a simulated chemical and conventional weapons scenario. The exercise scenario included triage and prescribed treatment procedures for simulated casualties. Work level demands ranged from light to intermittent heavy. Prior to the start of the exercise, each participant was instructed to drink one canteen of water, canteens were refilled, and water

points on the course were identified. Although the WBGT exceeded 90 °F between 1330 and 1530 hrs, the exercise continued under close supervision. Four minor heat exhaustion patients were treated during this FTX (Figure 1).

In June 1988, 229 reservists from the 44th Evacuation Hospital were deployed to the field for 8 days of annual training at Fort Hood, Texas. Training consisted of triage and prescribed treatment procedures for simulated casualties. Work level demands within the unit ranged generally from light to moderate. During this exercise, ground level WBGT readings were made using the Weksler WBGT kit and the electronic WBGT data loggers. Hourly WBGT information, obtained using the Weksler kit, was transmitted through the 341st Medical Group to Headquarters, 807th Medical Brigade for dissemination to units under its command and control.

A total of 18 heat casualties (heat exhaustion, syncope, non-specific heat effects) were treated during the 8 days of this brigade level exercise. Thirteen

heat casualties occurred on day 4, the hottest day, when the WBGT reached 90.3°F (Figure 1). There were no admissions for heatstroke and the majority of heat injuries (13 out of 18) treated during this FTX were from units other than the 44th Evacuation Hospital (6).

Wet bulb globe temperatures derived from the satellite data were compared with the ground readings obtained using the electronic WBGT data loggers (Table 1).

Table 1
Comparison of satellite-derived WBGT with contemporary readings from the electronic WBGT data loggers

DAY	TIME (hrs)	WBGT		ERROR
		SATELLITE	MEASURED	
0	0904	75.4°F	68.8°F	6.6°F
1	0842	70.9	69.4	1.5
2	1727	80.1	82.5	-2.4
3	0939	75.8	75.1	0.7
3	1716	81.1	84.9	-3.8
4	0917	78.9	79.5	-0.6
4	1705	81.6	85.7	-4.1
4	2034	75.2	78.2	-3.0
5	1654	74.9	78.6	-3.7
6	1642	73.1	77.4	-4.3
7	1631	68.0	74.9	-6.9

Adapted from table in reference #6.

For 11 satellite passes, carefully matched for geographical site and actual time, the satellite-derived WBGT data demonstrated an average error or "bias" of 1.8°F (too low) with a variation (standard deviation) of ±3.7°F around that bias. In the context of the inherent variability of the ground measurements (typical variation in point-to-point measurements within a 1 sq km satellite "pixel" size area at the hospital site was ±1.8°F; logger accuracy specification was ±0.9°F), these results were remarkably good.

DISCUSSION

The majority (31 out of 35 cases; 89%) of heat casualties seen during these three FTX's occurred when the daily maximum WBGT index exceeded 85°F. Current heat injury prevention guidance (1,3) is defined for the region between 78 and 90°F on the WBGT index scale. Within this 12 degree zone are 4 categories, ranging from 2 to 4°F in width, for which specific guidance has been established. The portable Weksler WBGT kit represents the existing technology alternative to the

full size WBGT device for Army units in the field. The data obtained from this device and the next generation of improved heat stress monitoring devices are vital for the prevention of heat injury. Field hospital units, properly trained and equipped with a WBGT measurement capability, can disseminate information to other units within their area of responsibility: Hourly WBGT data were communicated through the 341st Medical Group to brigade headquarters during the 1986 and 1988 FTX's. An unanticipated benefit derived from the decision to measure WBGT during FTX's was the interest demonstrated by unit personnel. Soldiers became acquainted with the operation of the Weksler WBGT Kit and knowledgeable on using the data to guide the intensity of training in the heat. A greater appreciation of the need to enforce water consumption recommendations was gained by hospital personnel as a result of their interest in on-site WBGT monitoring.

In the future, it is possible that near-real-time assessments of theater-wide WBGT conditions, anywhere in the world, may be available through satellite remote

sensing methods and Army tactical weather systems that are currently under development. Exploitation of this technology for heat stress assessment has the potential to provide commanders a way to significantly reduce heat injuries in training or operational settings. Although this preliminary study demonstrated reasonably close agreement between satellite-derived and on-site WBGT measurements, additional work is needed to refine these methods to a level of accuracy that will permit reliable resolution of the existing heat stress categories which have WBGT bandwidths of 2 to 4°F.

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FIGURE LEGENDS

Figure 1. Number of heat casualties treated as a function of the daily maximum WBGT. Fourteen training days at three FTX's are represented. Numerical heat stress categories I thru V are defined in FM 21-10, 1988. Color coded heat stress categories are defined in GTA 8-5-45, 1985.

HEAT CASUALTIES VS DAILY MAXIMUM WBGT